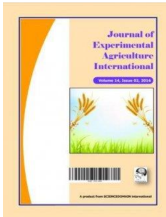

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Planting Spacing of Cultivated Soybean Intercropped with Cover Plants

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this work was to evaluate the influence of planting spacing in soybean intercropped with covering species in the Roraima savanna.
Study Design: The experimental design was a randomized complete block design with four replications.
Place and Duration of Study: The experiments were conducted at Embrapa Roraima, in Campo Experimental Água Boa, municipality of Boa Vista - Roraima state, in 2015 and 2016.
Methodology: Plots consisted in the spacing (0.45, 0.55 and 0.65 m) and the subplots were constituted by the cover plant species *Urocloa brizantha*, *Urocloa ruziziensis*, *Panicum maximum* and the treatment without intercropping. The used soybean cultivar was BRS Tracajá in two crops. The following variables had evaluated: plant height, number of grains per pod, number of pods per plant, 100-grain weight, plant dry matter, insertion of the first pod, grain yield, and dry matter of the covering species and of spontaneous vegetation.

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Results: Cover plants affected the plant height, number of pods per plant, insertion of the first pod, dry matter of cover species and yield of grains in soybean. The spacing did not influence the growth and production of the soybean crop, except positively in the number of pods per plant with the increased of spacing. The interaction of cover plants and spacing affected the weight of 100 grains, the insertion of the first pod and the dry mass of the cover species. Number of grains per pod and the dry mass of the soybean plants were not affected by the cover plants and by the spacing.

Conclusion: The *U. brizantha* species provids the highest production of dry matter intercropped with soybean, however, the yield of the crop decrease. The *U. ruziziensis* species is the most suitable for the cultivation intercropped with the crop. The used spacing do not influence the productivity.

Keywords: Competition; intercropped cultivation; forages; Glycine max; grain production.

1. INTRODUCTION

Brazil is the second largest soybean (*Glycine max*) producer in the world, following only the United States. In the 2015/2016 growing season, this crop occupied an area of 33.17 million hectares, totaling a production of 95.63 million tons; the average yield of soybean in Brazil was 2,882 kg ha^{-1}. In the same growing season, Roraima occupied an area of 24 thousand hectares, with a production of 79.2 thousand tons and totaling a productivity of 3,300 kg ha^{-1} [1].

Integrated systems can contribute to the production of soybean and to sustainability in different regions of Brazil, becoming an option to increase and diversify the income of producers, as well as for future improvements of no-till systems [2,3].

The intercropping with forage species is a long-term method and consists of the cultivation of two or more crops in the same place with the objective of maximizing the productivity and quality of the obtained production [4,5].

Intercropped cultivations with forage species from the genus Urochloa have been proving to be profitable and compatible, aiming at both straw and grain production. However, one of the limitations faced by producers for the adoption of the no-tillage system for soybean in the Cerrado of Roraima is related to the difficulty of establishing these plant species after harvesting commercial crops, due to the marked water deficit occurring from October to March.

In order to maximize the yield of a crop, the use of spacing and the used cultivar contribute most of the time to soybean yield. In this context, it is important to emphasize the spacing between rows to be used while sowing. According to Tourino [6], Procópio et al. [7], and Balena et al. [8], spacing can be managed in order to define a more suitable arrangement to obtain higher yields and the adaptation to harvesting fabaceae by machines. Also, by defining an adequate spacing, it is possible to provide good productivity and weed management, thus contributing to soil sustainability.

The objective of this work was to evaluate the influence of spacing and intercropping with cover crop species on the performance of soybean in the cerrado of Roraima.

2. MATERIALS AND METHODS

2.1 Location of Study Area

The experiment was conducted in the experimental field of Brazilian Agricultural Research Corporation (EMBRAPA), Água Boa - CEAB, in the municipality of Boa Vista - Roraima state; located at the geographical coordinates of reference: 02º49’11’’N, 60º40’24’’W and 85 m of altitude, in a soil classified as Yellow Latosol, whose analysis of properties was the following: pH (H_2O) = 5.4; Ca^{2+} = 1.28 $cmolc.dm^3$; $Mg^{2+}$$cmolc.dm^3$ = 0.2 $cmolc.dm^3$; K^+ $cmolc.dm^3$; = 0.19 $cmolc.dm^3$; Al^{3+} = 0.1; $cmolc.dm^3$ (H + Al) = 2.62 $cmolc.dm^3$; P_2O_5 = 14.18 $mg.dm^3$; SB= 1.67 $cmolc.dm^3$; T = 4.29 $cmolc.dm^3$; t = 1.77 $cmolc.dm^3$; V= 39% and m=6%, clay =136 g kg^{-1}; silt = 29.1 g kg^{-1} and sand = 834.7 g kg^{-1}.

The climate of the region, according to the classification of Köppen, is Aw type, tropical rainy, with an average annual precipitation of approximately 1,700 mm and relative air humidity around 70% [9].

The climatic data referring to maximum and minimum temperatures, and rainfall occurred during the experimental period are described in Fig. 1.

2.2 Study Design

The experimental design was a randomized complete block design in subdivided plots with four replications. Plots consisted in the spacing (0.45, 0.55 and 0.65 m) and the subplots were constituted by the cover plant species *Urocloa brizantha*, *Urocloa ruziziensis*, *Panicum maximum* and the treatment without intercropping. The used soybean cultivar was BRS Tracajá in two crops, from June to September 2015, and from May to September 2016.

The plant stand was the same for all treatments, varying only as for the number of plants per linear meter, which were adjusted to the different spacing. The subplots occupied areas of 18.9 m^2 for the 0.45 m spacing; 23.1 m^2 for the 0.55 m spacing, and of 27.3 m^2 for the 0.65 m spacing. The useful area of each subplot consisted of 5.0 x 2.25 m (11.3 m^2) for the 0.45 m spacing; 5.0 m x 2.2 m (11 m^2) for the 0.55 m spacing, and 5.0 x 1.95 m (9.8 m) for the 0.65 m spacing, consisting of five, four and three rows of soybean plants, respectively, in which 0.50 m at each end of the subplots were excluded, for the realization of the evaluations, corresponding to the useful area.

Before the sowing of soybean in 2015, the area was prepared with two disk plowing and one with a leveler to revolve the soil, since it remained for six years without any cultivation. Fertilization consisted of 100 kg ha^{-1} of P_2O_5, in the source of simple superphosphate + 50 kg ha^{-1} of FTE BR 12 + 10 kg ha^{-1} of N (urea source) applied in the planting grooves, and 120 Kg ha^{-1} of K_2O in the source of potassium chloride, with 50% applied during planting and 50% during coverage, 30 days after emergence (DAE), together with seeds of the cover species.

Soybean sowing was performed in open grooves with a mechanized ridger during the first year of cultivation. Therefore, seeds were inoculated with *Bradyrhizobium japonicum*.

Subsequently, it was sown manually, using densities of 280,000 ha^{-1} seeds, held in June 2015. In the second year of cultivation (2016), sowing was performed mechanically in May in no-tillage, using a SEMEATO SAN 200 planter, over the straw formed by the cover species from the previous year.

Covering species were sown 30 days after the emergence of the soybean seedlings (DAE), using 30 kg ha^{-1} of seeds for the species *Urocloa brizantha* and *U. ruziziensis*, and 10 kg ha^{-1} for cv. Massai, mixed with 60 kg ha^{-1} of K_2O planted between the rows of soybean plants.

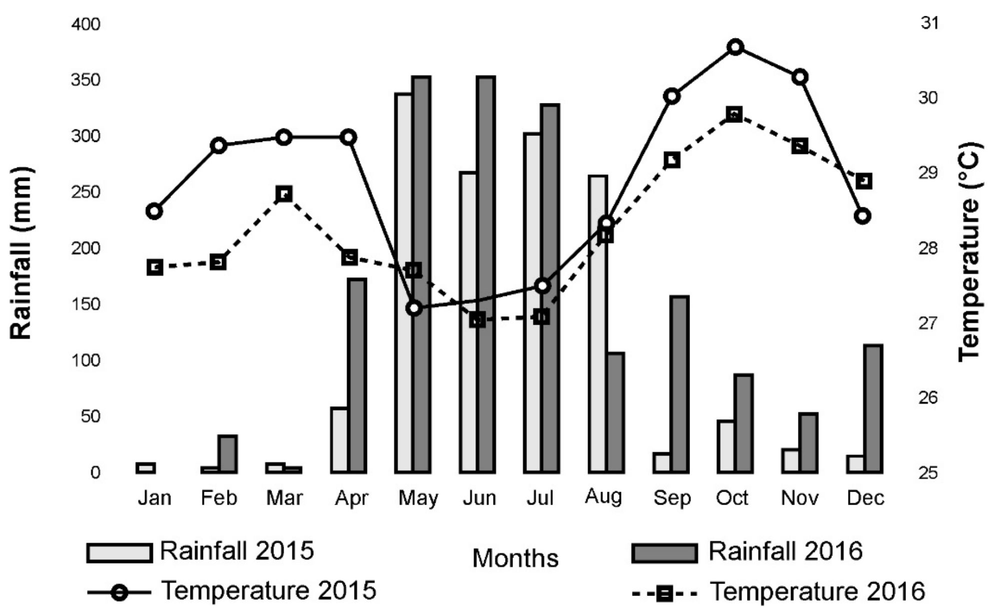

Fig. 1. Means of rainfall and maximum and minimum temperatures

Weed control was performed at 25 DAE, at stage V4, using the herbicides Flex (Fomesafen) and Fusilade (Fluazifop-p-butyl), at doses recommended by the manufacturers.

In the second cultivation year (2016), according to the covering obtained from the previous planting, forage was dried with Glyphosate + Flumyzin (Flumioxazin), then soybean was planted, and after 20 (DAE), Flex (Fomesafen) + Verdict (Haloxyfop-Methyl) was applied.

2.3 Data Collection

During the development of the crop and after the harvesting of soybean, the following agronomic characteristics were evaluated: plant height, evaluating ten random plants in the useful area, measuring them from the neck of the plant until the end of the main stem; number of grains per pod - the total number of grains from ten plants was counted, and the result was divided by the total number of pods; number of pods per plant - ten random plants were collected in the useful area of the sub-plot, obtained by counting the total number of pods and calculating the average; 100-grain weight, determined by weighing one hundred grains from the useful area, later corrected to 13% moisture; plant dry matter - ten plants were randomly collected, dried in an oven until constant weight and weighed on a precision scale; insertion of the first pod, determined from the collection of ten random plants in the useful area of each subplot, measuring from the neck of the plant until the insertion of the first pod; grain yield - the grains harvested from the useful area of each plot were weighed, estimating the production for one hectare, and correcting grain moisture to 13%.

One-hundred twenty days after the harvest of soybean, the dry matter of the cover crop area and the spontaneous vegetation contained in the treatments without intercropping were evaluated. To determine the dry matter of the covering species, samples were collected using a 0.50 x 0.50 m square iron, according to the Braun-Blanquet methodology (1950) [10]. After that, they were taken to the laboratory in order to determine the dry matter of plants, through oven drying until constant weight at a temperature of 65°C, and then they were weighed on a precision scale.

2.4 Data Analysis

Data on the production components of soybean and the dry matter of forage species and spontaneous vegetation were submitted to analysis of variance using the F test. These data refer to the average of two cultivation years (2015 and 2016). For the comparison between the means, the Tukey's test was carried out at 5% probability, with the help of the SISVAR computational application. The variable about shoot dry matter of covering species and spontaneous plants was transformed into kg ha^{-1} to discuss data.

3. RESULTS AND DISCUSSION

3.1 Height of Plants

The height of plants (PH) was influenced by the covering species intercropped with soybean, whose means are presented in Table 1.

The greatest PH of soybean intercropped with *P. maximum* cv capim massim may be related to the characteristic of the species. The forage plant cv. massai presents a smaller size, forming clumps with a mean height of 0.60 m, and presenting fine leaves, measuring 1 cm in width [11]. Possibly, these characteristics may have contributed to a smaller competition with the intercropped species, since soybean reaches a greater height.

For the intercrop with the species *U. ruziziensis*, due to a slower initial growth, soybean probably showed greater vigor in the initial development of plants, but did not differ in height from *P. maximum*, as well as the low spontaneous vegetation in the area of treatments without intercropping, which were basically composed of lower plants where there was greater competition of the culture.

The lower PH found for the intercrop with *U. brizantha* can be justified by the characteristics regarding the forage cultivar introduced in the intercrop with BRS Tracajá soybean. It is possible to state that, under these conditions, the intra-species competition was significant, but with an acceptable height of soybean plants.

3.2 Number of Pods per Plant

The number of pods per plant (NPP) was influenced by the spacing (Table 2) and also by the intercrop with covering species (Table 1). A significant difference between spacing was also verified by Silva et al. [12], in which there was a higher NPP in a spacing of 0.50 m.

Table 1. Average plant height (PH), number of pod per plant (NPP) and yield of soybean crop cv. BRS Tracajá, intercropped with covering plants in Boa Vista - Roraima State, 2017

Covering plants	PH (cm)	NPP	Yield (kg ha^{-1})
Urocloa brizantha	0.83 b*	59.0b	2631.1 b
Urocloa ruziziensis	0.87 ab	59.2ab	2880.8 ab
Panicum maximum	0.89 a	62.9ab	2713.9 ab
Spontaneous vegetation	0.85 ab	67.1a	2920.4 a
VC%	3.6	11.3	9.1

**Means followed by the same lowercase letter in the column do not differ by Tukey's test, at 5% probability*

Table 2. Average number of pods per plant intercropped with three types of spacing (cm) in between rows of soybean cv. BRS Tracajá, in Boa Vista - Roraima State, 2017

Spacing (m)	Number of pods per plant
0.45	59.5 b*
0.55	58.4 b
0.65	68.2 a
VC %	11.1

**Means followed by the same lowercase letter in the column do not differ by Tukey's test, at 5% probability*

As for the different covering species used in the intercrop with soybean, it is possible to observe that the spontaneous vegetation, *U. ruziziensis* and *P. maximum*, provided soybean with the highest NPP and the last two species did not differ from *U. brizantha* (Table 1). Among the elements used in the production factor, NPP is the characteristic that most contributes to the grain yield in the soybean crop, since it presents a higher correlation with production [13].

3.3 Grain Yield

Grain yield was influenced by the covering crops; the cultivation without intercropping was the best treatment, followed by the species *U. ruziziensis* and *P. maximum* (Table 1). Productivity is closely linked to the production components of soybean and depends directly on the interaction of the genotype with the environment [14]. According to Albuquerque et al. [15], Castagnara et al. [16], Albuquerque et al. [17] and Werner et al. [3], large crops show higher yields in single crops.

3.4 Number of Grains per Pod

The number of grains per pod in the soybean crop was not influenced by the spacing and the cover crops used in this work, similar to other works with the same crop [18,19,20,21,22].

3.5 100-grain Weight

There was an interaction between the used spacing and the covering plants for the 100-grain weight (W100G). When the spacing was split within each covering, it was possible to observe that *U. ruziziensis* and the spontaneous vegetation influenced the W100G of the culture (Table 3).

In the intercrop with *U. ruziziensis*, soybean reached a higher W100G at the spacing of 0.45 and 0.55 m. Possibly, a smaller spacing allowed lower weed interference in the soybean crop, due to the closing of the crop canopy. As for *U. ruziziensis*, there was a smaller initial development at these spacing. As for the outcome of the covering species within each spacing level, no significant difference was observed (Table 3).

Table 3. Averages of the 100-grain weight obtained according to the interaction between spacing and covering plant intercropped with soybean cv. BRS Tracajá under different spacing in Boa Vista - Roraima, 2017

Covering plants	100-grain weight (g)		
	45 cm	55 cm	65 cm
Urocloa brizantha	11.8 aA*	12.1 aA	11.8 aA
Urocloa ruziziensis	13.3 aA	11.3 abA	10.8 bA
Panicum maximum	11.9 aA	12.3 aA	12.8 aA
Spontaneous vegetation	11.7 abA	13.5 aA	11.3 bA
VC1%		7.88	
VC2%		9.23	

**Means followed by the same lowercase letter on the line and uppercase in the column do not differ by Tukey's test, at 5% probability*

Komatsu et al. [23], while studying the effect of plant spacing on the behavior of specific growth soybean cultivars, observed a greater grain weight when the 0.45 m spacing was used, highlighting this effect among the characteristics of long-cycle soybean cultivars. According to Bianchi et al. [24], crops with good potential for production cause greater reduction of environmental resources, reducing their availability to other competing species and thereby becoming more competitive with weeds.

No significant differences were found as for the W100G intercropped with the species *U. brizantha* and *P. maximum* cv. massai (Table 3). This result may be related to the genetic limit of the forage cultivar and/or species. In a study conducted by Castagnara et al. [16], it was also not possible to find differences in terms of W100G in the joint sowing of soybean and *U. brizantha*.

3.6 Plant Dry Mass

The spacing and cover plants used did not influence the dry mass of the soybean plant, similar results were found in other studies with the same crop [25,26].

3.7 First Pod Insertion

Table 4 presents the values about the first pod insertion (FPI) characteristic in the soybean crop, for the interaction between spacing and covering.

As for the spacing within each covering level, it was observed that the spacing of 0.65 m influenced the intercrop when the *P. maximum* species was used, decreasing the height of the FPI. The spacing with the highest FPI height was 0.45 and 0.55 m. As for the other covering species, no significant differences were observed (Table 4). A greater spacing allowed lower plants, compared to those of the 0.55 and 0.45 m spacing; thus, there was a small variation in FPI. According to Cruz et al. [27], the importance of evaluating this variable informs if the minimum height may or may not provide losses during the harvesting process by the cutting bar of the harvester.

In the 0.55 m spacing, *U. brizantha* negatively influenced the FPI, resulting in the lowest height, but with similar values to the other treatments (Table 4). This effect may be related to the competition of the intercrop and the variation in the environment, modifying the height of plants. Torres et al. [28] state that the environmental factors that interfere in the FPI are the same that can influence the height of plants, so it is possible that the height of the first pod has undergone a variation according to the height of soybean plants.

The *U. brizantha* species, in general, was the one that influenced in terms of lower height in the FPI, mainly due to the intense competition that occurs with the culture. *U. brizantha* is more demanding for light, thus becoming more competitive for the solar radiation that reaches the soil for germination and vegetative development, and the FPI has a direct correlation with the use of light in the lower part of the canopy; thus, the more light reaches the lower part of the canopy of the soybean crop, the lower the node of the first pod and, consequently, the height of the insertion of the first pod.

A study by Pereira et al. [29] showed a negative influence on the intercropping with *U. decumbens* species, causing a significant effect, and reducing the height of the first pod to 11.1 cm, when this forage was sown in the soybean rows, 25 days after sowing.

Table 4. Averages of the first pod insertion (FPI) obtained according to the interaction between spacing and covering plant intercropped with soybean cv. BRS Tracajá in three spacing between rows, in Boa Vista - Roraima State, 2017

Covering plants	First pod insertion		
	45 cm	**55 cm**	**65 cm**
Urocloa brizantha	15.9 aB*	16.6 aB	16.3 aB
Urocloa ruziziensis	17.9 aA	17.5 aAB	18.1 aA
Panicum maximum	18.4 aA	18.4 aA	16.5 bB
Spontaneous vegetation	17.1 aAB	17.2 aAB	16.4 aB
VC1%		5.78	
VC2%		4.54	

**Means followed by the same lowercase letter on the line and uppercase in the column do not differ by Tukey's test, at 5% probability*

Table 5. Averages of the dry matter of covering species (kg ha^{-1}), obtained according to the interaction between spacing and covering plant intercropped with soybean cv. BRS Tracajá, in three spacing between rows, in the experimental field of Embrapa, in Boa Vista - Roraima State, 2017

Covering plant	Dry matter (kg ha^{-1})		
	45 cm	55 cm	65 cm
Urocloa brizantha	74.99 bA*	83.56 abA	92.44 aA
Urocloa ruziziensis	54.60 aB	63.74 aB	68.08 aB
Panicum maximum	69.58 aAB	64.95 aB	70.21 aB
Vegetação espontânea	17.75aC	16.70 aC	15.03 aC
VC1%		14.7	
VC2%		15.1	

**Means followed by the same lowercase letter on the line and uppercase in the column do not differ by Tukey's test, at 5% probability*

3.8 Dry Matter Yield of Covering Plants Had

The shoot dry matter yield of covering plants had a significant effect for the interaction between spacing and covering plants (Table 5).

Opposite results were obtained by Mata et al. [30] with lower values for the same variable, which can be explained by the smaller spacing between soybean rows (0.40 m) used by these authors, and the 20 to 30-day sowing gap period, which favored the development to the detriment of forage.

The Urocloa species show greater root growth, which may result in better development conditions during the dry season [31].

U. ruziziensis becomes promising in the production of straw when intercropped with soybean in the no-tillage system. Pacheco et al. [32] mention that out of the species used to form straw in the off-season, *U. Ruziziensis* is important; even with a low initial development, it has good regrowth capacity and dry matter gains, thus being an alternative to intercropping and no-till systems.

4. CONCLUSION

Cultivar BRS Tracajá presents better grain yield in the single crop, and intercropped with *Urocloa ruziziensis* and *Panicum maximum*. The highest dry matter yield occurs for the *Urocloa brizantha* species; however, it causes the greatest reduction in soybean yield. The *U. ruziziensis* and *P. maximum* species present the best use potential to establish themselves in intercrop with soybean, reaching good dry matter productivity and less interference in soybean production components. The used spacing does not influence the productivity of cultivar BRS Tracajá.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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